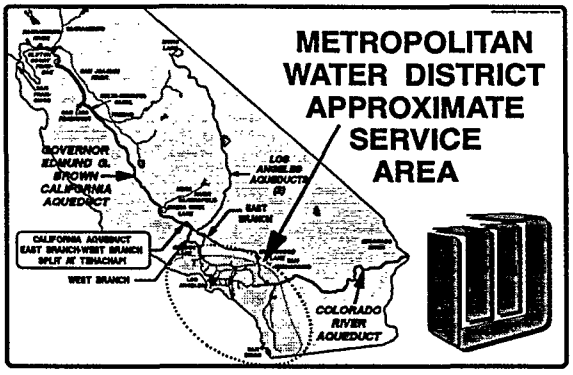
4/23/98 Ca/Nv Section AWWA

Evaluation of Perchlorate Rejection by Nanofiltration and Reverse Osmosis Membranes

Sun Liang, Ph.D., P.E.
Leslie Palencia, P.E.,
and Jeanne-Marie Bruno, P.E.
The Metropolitan Water District of Southern California
J. Richard Phillips, Ph.D.
Harvey Mudd College



Perchlorate

- Ammonium perchlorate (NH_4ClO_4)
- Ingredient for solid rocket fuels, explosives, munitions, and fireworks
- Forms anionic ion (ClO_4^-) in water
- High water solubility (107.4 g/L at O°C to 424.5 g/L at 85°C)
- Concentrated oxygen source
- Molecular size - 6-10 Å

Health Effects

- Inhibits hormone production by thyroid
- No federal or state regulations
- California Provisional Action Level of 18 μg/L

Occurrence

- Las Vegas Wash (as high as 1,700 μg/L)
- Lake Mead (10-24 μg/L)
- Colorado River Water in Metropolitan's System (5-7 μg/L)
- Groundwaters in Southern California (Nondetect to >500 μg/L)

Treatment Options

- Granular activated carbon (GAC)
- Ion exchange
- Membranes
- Anoxic biodegradation
- Hybrid system

Membrane Study Objectives

- Compare ClO_4^- removal with nanofiltration (NF) vs. reverse osmosis (RO) membranes
- Evaluate the effect of ClO_4^- feed concentration on ClO_4^- rejection rates
- Evaluate the effect of recycling the retentate

Mechanisms of Perchlorate Rejection

Complex perchlorate-membrane chemical interaction involves:

- Co-ion repulsion
- Diffusion
- Sorption

Experimental Design

- Spiral Wound Membranes
  - ➤Film Tech N70 4040-B (NF)
  - ➤Fluid Systems TFC 4820-ULPT (RO)
- Post treatment
- Spiked ClO_4^- Dosages:
  - ➤Low: 20-50 μg/L
  - ➤Medium: 500-800 μg/L
  - ➤High: 1,000-2,000 μg/L

Experimental Design (Cont'd)

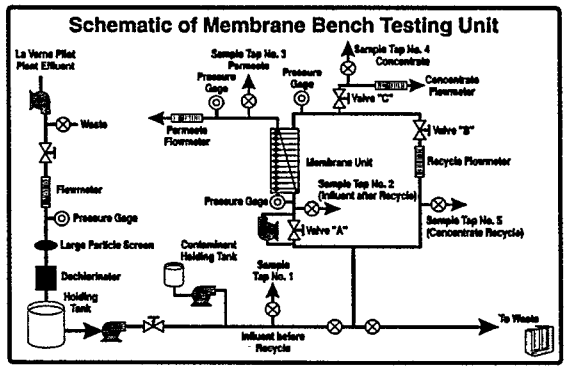
- Brine recycle at 50% of influent flow
- Test duration 3 hours
- Sampled 2nd and 3rd hour at influent, influent with recycle, permeate, and brine
- Measured ClO_4^-, total organic carbon (TOC), conductivity, UV_{254} absorbing organics, turbidity, and particle counts

Membrane Characteristics

Type	MWCO	Surface Charge	Compo-sition	Surface area (ft^2)	Flux (GFD)	Recovery (%)
NF	300 Da	Negative Charge	Thin Film Composite	82	15	20
RO	-----	Negative Charge	Thin Film Composite	72	15	20

MWCO - molecular wieight cutoff

Schematic of Membrane Bench Testing Unit

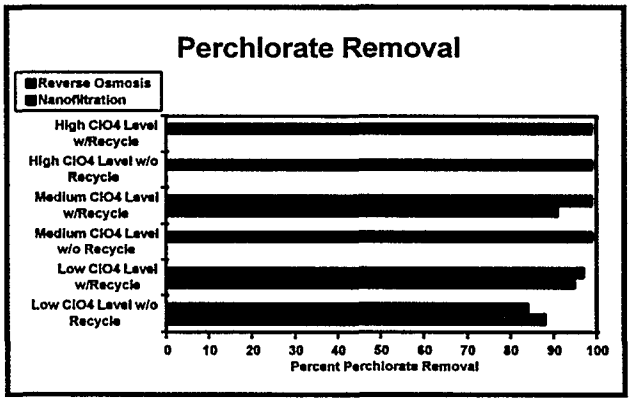


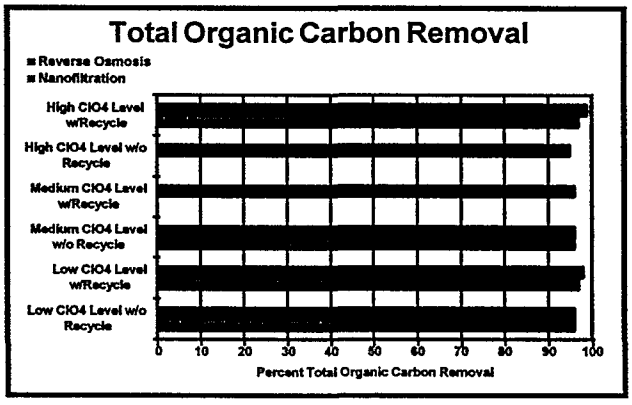
Membrane Influent Water Quality

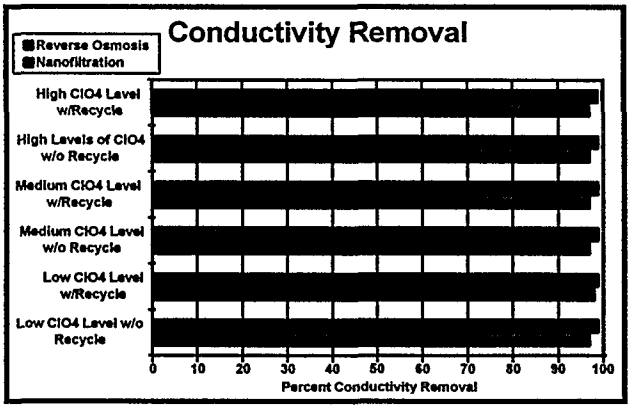
Source Water	CRW
Total Organic Carbon	2.40 - 3.05 mg/L
UVA_{254}	0.024 - 0.032 abs/cm
Conductivity	969 - 1030 µmhos/cm
Temperature	20.4 - 21.5 °C
pH	8.09 - 8.24
Turbidity	0.12 - 0.78 NTU
Particle Count	113 - 1590 /mL

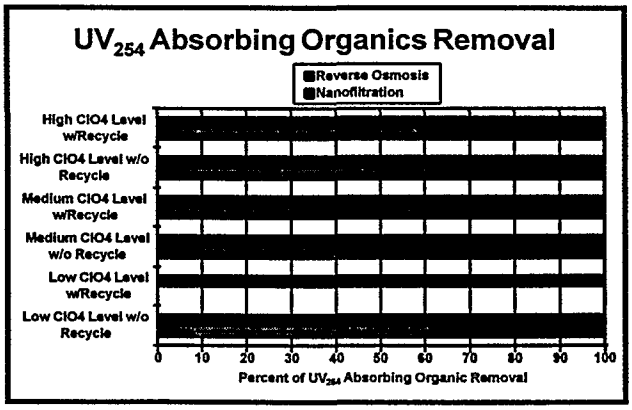
Specific Flux for Membranes

Membrane	Average Pressure (psi)	Average Permeate (gpm)	Average Flux (GFD)	Specific Flux (GFD/psi)
NF	87	0.86	15	0.17
RO	106	0.76	15	0.14

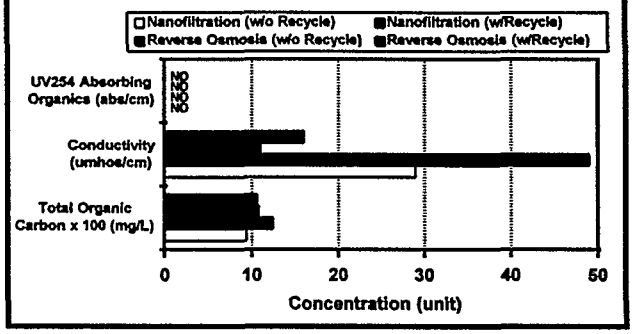








Permeate Characteristics



Brine Characteristics

- Perchlorate, TOC, conductivity, UV_{254} absorbing organics were concentrated in the brine
- Membrane systems concentrated ClO_4^- in brine by approximately 20-50 percent

Preliminary Findings

- NF and RO membranes can effectively remove ClO_4^- from CRW
- NF and RO performed equally well for ClO_4^- removal at low levels of ClO_4^- and lowered ClO_4^- concentration below 4 μg/L in permeate

Preliminary Findings (Cont'd)

- RO performed better than NF for ClO_4^- removal at medium and high levels of perchlorate
- Brine recycle did not significantly affect ClO_4^- percent rejection, but produced higher ClO_4^- levels in permeate

Preliminary Findings (Cont'd)

- Total organic carbon, conductivity, and UV_{254} absorbing organics can also be effectively reduced by membranes
- Conductivity increased in permeate when brine recycled
- Brine disposal/treatment is required